

## TITLE OF THE INVENTION

Semiconductor Device and Method of Manufacturing the Same

## BACKGROUND OF THE INVENTION

### Field of the Invention

5           The present invention relates generally to semiconductor devices and particularly to semiconductor devices that can be packaged with enhanced anti-bendability.

### Description of the Background Art

10           In recent years, semiconductor devices have been further reduced in size and further increased in density to meet a demand for smaller and lighter mobile phones, mobile information equipment and other similar electronics and electronic equipment. To meet this demand there has been proposed bare-chip packaging, a technique applied in mounting an LSI chip directly on a printed circuit board.

15           Reference will now be made to Figs. 5A and 5B to describe bare-chip packaging. As a bare chip, an LSI chip 7 has thereon an electrode on which ball-bonding is for example employed to provide a metal bump 14 thereon to serve as an external connection electrode. With reference to Fig. 5A, with metal bump 14 aligned with an electrode 10 provided on a printed circuit  
20 board 9 to be packaged, LSI chip 7 is packaged on printed circuit board 9 facedown. Fig. 5B shows a complete packaging.

25           The market for mobile equipment such as mobile phones and PHSs has significantly expanded. As such, technological innovation has been promoted therefor and bare-chip packaging has thus been increasingly adopted. Conventionally, a package is impaired in reliability generally when temperature cycle causes thermal stress and thermal distortion resulting in defects. In addition, mobile equipment carried by a user can disadvantageously bend when it receives external force. Furthermore, disadvantageous bending stress can instantly occurs when mobile  
30 equipment is dropped. Furthermore, in a process for manufacturing such mobile equipment, bending stress can occur in a printed circuit board while components are packaged. As such, it is also an important condition that mobile equipment have a mechanically reliable structure impervious to

bending stress and the like.

Herein, the semiconductor device shown in Figs. 5A and 5B has main components with their respective Young's moduli, as follows:

LSI chip (Si): approximately  $12$  to  $14 \times 10^{10}$  N/m<sup>2</sup>

5 Printed circuit board: approximately  $0.5$  to  $2.5 \times 10^{10}$  N/m<sup>2</sup>  
and it can be understood that LSI chip 7 is formed of a material hard to bend as compared with the printed circuit board. As such, when force is exerted on printed circuit board 9 to bend it, LSI chip 7 does not accordingly bends. Thus, stress concentrates at a solder connection connecting printed circuit  
10 board 9 and LSI chip 7 together and when the limit of the stress has been reached the solder connection disadvantageously breaks and thus disconnects.

The present invention therefore contemplates a semiconductor device capable of alleviating such a disadvantage as described above when  
15 the entirety of a printed circuit board receives force exerted to bend it, and a method of manufacturing the same.

#### SUMMARY OF THE INVENTION

To achieve the above object the present invention can provide a semiconductor device including a semiconductor substrate having a surface  
20 provided with an external connection electrode and a surface opposite that with the external connection electrode, abraded and reinforced with a back-surface reinforcement member. As such, the semiconductor substrate can be abraded and thus reduced in thickness to bend in response while a level of rigidity can be ensured as the semiconductor substrate is reinforced with the  
25 back-surface reinforcement member.

In the present invention preferably the back-surface reinforcement member is formed of resin. Since resin has a low elastic modulus it can reinforce the semiconductor substrate without affecting the bendability of the semiconductor device.

30 In the present invention still preferably the resin is formed of a material having an elastic modulus of  $1.5 \times 10^6$  N/m<sup>2</sup> to  $5.0 \times 10^6$  N/m<sup>2</sup>. More specifically, the resin is selected from the group consisting of resin of rubber type, resin of silicone type, resin of epoxy type, resin of polyimide

type and resin of urethane type. Thus, the resin can reinforce the semiconductor substrate without impairing the bendability of the substrate. Applying such resins can also prevent the substrate from chipping or being scratched.

5 The present invention provides a method of manufacturing a semiconductor device including the steps of: abrasing a surface of a semiconductor substrate opposite to that of the semiconductor substrate provided with an external connection electrode, and applying resin on the abraded surface of the semiconductor substrate. As such, the  
10 semiconductor device can be reduced in thickness to bend in response. As the semiconductor substrate is reinforced with resin, the semiconductor device can be produced with a level of rigidity ensured.

In the present invention preferably the method further includes the step of cutting the semiconductor substrate after the step of applying. As  
15 such, the present method can be readily applied in mass-production.

In the present invention still preferably the method further includes the step of grinding the surface of the semiconductor substrate to be abraded. As such, the semiconductor substrate can be processed in a reduced time.

In the present invention, preferably, in the step of applying, the  
20 resin is printed. As such, highly viscous resin can also be distributed and thus applied.

Furthermore, in the present invention, preferably, in the step of applying, the resin is applied by spin-coating. Thus the resin can be applied rapidly, reduced in thickness, uniformly.

25 The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

30 In the drawings:

Figs. 1A-1E are cross sections each showing a step of a process for manufacturing a semiconductor device in a first embodiment of the present invention;

Fig. 2 is a cross section of a semiconductor device in a second embodiment of the present invention;

Fig. 3A is a view for illustrating a model in the form of a rectangular parallelepiped employed for considering stress occurring when an LSI chip is bent and Fig. 3B illustrates the model that is bent;

Fig. 4 is a view of the Fig. 3A model provided for considering an amount by which the center of the model descends when the model is bent;

Fig. 5A illustrates a procedure of bare-chip mounting in prior art and Fig. 5B is a cross section of a completed bare-chip package.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

### First Embodiment

Fig. 3A shows a model in the form of a rectangular parallelepiped having a thickness  $a$  and a width  $b$ , as seen in cross section, applied to consider how LSI chip 7 bends. When this model is bent as shown in Fig. 3B, its upper side as seen in the figure expands due to tensility, its lower side as seen in the figure contracts due to pressure, and intermediate therebetween exists a neutral layer which neither expands nor contracts. Assuming that on average the model's expansion and contraction are balanced, the neutral layer includes the barycenter of the cross section. If the neutral layer has a small portion  $dx$  forming an angle  $d\theta$  with respect to a center of curvature  $C$  and having a radius of curvature  $\rho$  then a thin layer  $dz$  spaced from the neutral layer by a distance  $z$  and having an area  $dS$ , which is equal to  $b dz$ , in cross section has an expansion rate of:

$$[(\rho + z) d\theta - \rho d\theta] / \rho d\theta = z/\rho \quad \cdots (1).$$

As such, this layer experiences a tensility  $dT$  of  $E(z/\rho)dS$ . If a stick neither expands nor contracts on average, its upper half as seen in cross section experiences tensility and its lower half as seen in cross section experiences pressure. If this model has a Young's modulus  $E$  then for the entirety of the cross section a bending moment is given in the following expression:

$$M = \int z dT = \frac{E}{\rho} \int z^2 dS = \frac{E}{\rho} \int_{-a/2}^{a/2} b z^2 dz = \frac{E}{\rho} \cdot \frac{a^3 b}{12} \quad \cdots (2).$$

Accordingly, as shown in Fig. 4, let us assume that this model is supported

at two points spaced by a length  $L$  and also has its center with a weight having a mass  $m$  ( $W = mg$ ) suspended therefrom.

Symmetry allows each supporting point to exert a supporting reaction force  $W/2$  upward. If balance in moment about an axis perpendicular to the plane of the figure is considered for a portion extending from a plane PQ, which is spaced from the model's center O by a distance  $x$  larger than 0, to a supporting point, then for plane PQ bending moment  $M$  is given by an expression (2) and, with supporting reaction force  $W/2$  contributing to  $(L/2 - x) \cdot W/2$ , there can be obtained an expression (3):

$$\frac{E}{\rho} \frac{a^3 b}{12} = \left( \frac{L}{2} - x \right) \frac{W}{2} \quad \cdots (3).$$

From this expression, radius of curvature  $\rho$  is obtained as a function of  $x$ . In general, a curve  $y = f(x)$  has a curvature represented by  $\rho^{-1} = y'' / \{1 + (y')^2\}^{3/2}$ . Assuming that  $|y'| \ll 1$ , if its terms of higher than the first degree can be neglected, then

$$y'' = \frac{6W}{Ea^3 b} \left( \frac{L}{2} - x \right) \quad \cdots (4)$$

is obtained. Herein, if  $y = 0$  and  $y' = 0$  are applied for  $x = 0$  then an expression (5) is obtained, as follows:

$$y = \frac{6W}{Ea^3 b} \left( \frac{Lx^2}{4} - \frac{x^3}{6} \right) \quad \cdots (5).$$

If the center descends by an amount  $e$  then  $y = e$  for  $x = L/2$ . Therefore, from expression (5), Young's modulus  $E$  is obtained, as represented by an expression (6):

$$E = \frac{WL^3}{4ea^3 b} \quad \cdots (6).$$

This is transformed to obtain amount  $e$ , as represented by an expression (7):

$$e = \frac{WL^3}{4Ea^3 b} \quad \cdots (7).$$

It can be understood that amount  $e$  is in inverse proportion to the cube of thickness  $a$  of LSI chip 7. More specifically, if LSI chip 7 has large thickness  $a$  it is less flexible, which increases the possibility that when printed circuit board 9 is bent the chip cannot bend accordingly.

5 As such, in order for the entirety of a package to bend in response, reducing LSI chip 7 in thickness can be effective.

Initially, reference will be made to Fig. 1E to describe a structure of a semiconductor device in the present embodiment. A single wafer 1 is used to provide a plurality of LSI chips 7. Each LSI chip has a circuit side 2  
10 formed thereon and having a surface (a lower surface, as seen in Fig. 1E) provided with a solder ball 6 serving as an external connection electrode. Substrate 1 has a back surface, opposite to the surface with the external connection electrode, with resin 5 applied thereon.

Reference will now be made to Figs. 1A-1E to describe a method of  
15 manufacturing a semiconductor device in the present embodiment.

Fig. 1A shows a cross section of wafer 1 used to produce a plurality of semiconductor chips. Wafer 1 has circuit side 2 thereon provided with an electrode formed for example of aluminum. Circuit side 2 also has a wiring pattern completed to allow its surface to be later provided with solder ball 6  
20 serving as an external connection electrode and arranged in matrix.

As shown in Fig. 1A, a protection tape 3 is stuck on a surface of circuit side 2 of wafer 1 (hereinafter referred to as the back surface of wafer 1) in abrasing a side opposite that having circuit side 2. Then, as shown in Fig. 1A, wafer 1 is set on an abraser 4 to have its back surface abraded.

25 Typically in producing a semiconductor device an ingot is cut to have a wafer thickness and then abraded with a wafer lapper. This wafer lapper may be used to abrase the back surface of wafer 1, since the wafer lapper can abrase a large number of wafers simultaneously and thus contribute to high productivity. The wafer is set on a turntable and an abrasive liquid  
30 containing an abrasive is used to mirror-finish the wafer.

Note that the wafer may be ground before it is abraded. If it is roughly ground the whole process time can be reduced. It should be noted, however, that after it is ground it must be abraded and thus mirror-finished,

since grinding wafer 1 often results in the wafer having its processed surface with small scratches and wafer 1 thus reduced in thickness may crack at such scratches when the wafer experiences force exerted to bend it.

5 The thickness of wafer 1 to be provided by abrasing the wafer depends on the size of wafer 1, although for example a thickness reduced to be as small as approximately 50  $\mu\text{m}$  is sufficient to be in effect impervious to bending.

Then, as shown in Fig. 1B, abraded wafer 1 is removed from abrasor 4 and surface protecting tape 3 is removed from the wafer.

10 With reference to Fig. 1C, resin 5 is applied on the back surface of wafer 1 to serve as a member reinforcing the back surface of the wafer. In doing so, the wafer is printed or spin-coated with the resin. One of the techniques is employed to correspond to the resin to be used. For example, a highly viscous resin would be appropriately applied if it is printed, since if  
15 the resin is applied by a spinner it may not be distributed satisfactorily. Initially, a mask is prepared. Initially, a mask is designed to allow resin to be applied only on a wafer. The resin is only required to have a thickness on the order of several tens  $\mu\text{m}$ . As such, the resin is applied on a mask prepared to be as thick as targeted and thereon a squeegee is scanned to  
20 print the resin.

In contrast, if less viscous resin is used, spin-coating would be faster in applying the resin in reduced thickness and uniformly. Wafer 1 is placed on a spinner and an appropriate amount of resin is then supplied thereon. Then the spinner is turned to cause centrifugal force to distribute  
25 and thus apply the resin on the wafer.

Then, with reference to Fig. 1D, solder ball 6 is provided to serve as an external connection electrode. In this step, a ball mainly formed for example of tin/lead eutectic alloy is placed together with flux and an electrode is formed by reflowing. The external connection electrode is not  
30 limited to solder ball 6 and it may be an electrode in a different form. In forming the electrode in the different form it may for example be plated and thus grown.

Finally, with reference to Fig. 1E, wafer 1 is cut along a dicing line to

provide individual semiconductor chips 7. Thus as a semiconductor device completes semiconductor chip 7 with solder ball 6 connected thereto.

Although Fig. 1E shows only two individual semiconductor chips cut apart, this cutting step in effect provides a large number of semiconductor chips cut apart from each other.

Note that while in the above exemplary method the abrasing step is provided after the formation of a wiring pattern for circuit side 2, this abrasing step may be provided for example before or during the formation of circuit side 2.

Furthermore, the abrasing step can be eliminated if any pre-process is used to previously prepare wafer 1 of approximately several tens  $\mu\text{m}$  in thickness.

The present invention can provide a semiconductor device wherein semiconductor chip 7 has a surface provided with an external connection electrode and a surface opposite that with the external connection electrode, abraded to reduce semiconductor chip 7 in thickness to allow semiconductor chip 7 itself to flex in response to bending-force. When a substrate with semiconductor chip 7 packaged receives force and thus bends, together with the substrate the chip can accordingly bend to alleviate stress in solder ball 6 or a solder connection so as to prevent the solder connection from breaking. Furthermore, resin having a low elastic modulus (a low Young's modulus) can be applied on the abraded surface of semiconductor chip 7 to reinforce the chip without having any effect on the bendability of the chip configured as above. Resin 5 can protect semiconductor chip 7 to eliminate the risk of semiconductor chip 7 chipping or being scratched and thus cracking. As such, semiconductor chip 7 can be more readily handled and thus enhanced in mechanical reliability.

Preferably, resin 5 is of material having a small elastic modulus of approximately  $1.5$  to  $5.0 \times 10^6 \text{ N/m}^2$  since resin 5 with such a small elastic modulus does not impair the bendability of LSI chip 7. Such a value of elastic modulus is small relative to that of LSI chip 7 and it is thus a negligible value for the entirety of a package, and applying resin 5 on LSI chip 7 can prevent the chip from chipping or being scratched, to allow the



chip to be handled more readily. Resin 5 is applied in an amount that can be set as desired in a range that does not affect on the bendability of the entire package. Desirably, resin 5 is reduced in thickness in a range that can prevent LSI chip 7 from chipping or being scratched, to approximately several tens  $\mu\text{m}$  as the package can be decreased in thickness and its material cost can also be reduced.

Specifically, resin 5 having the above elastic modulus can be resin of rubber type, silicone type, epoxy type, polyimide type or urethane type.

Furthermore the present invention can provide a method of manufacturing a semiconductor device wherein after the initial half of a wafer process is completed and before a wafer is diced the wafer can be abraded and thereon resin can be applied to produce a large number of packages simultaneously in a single process.

#### Second Embodiment

The present embodiment shows by way of example the Fig. 1E semiconductor chip 7 bare-chip packaged on printed circuit board 9. As a result, such a structure as shown in Fig. 2 is obtained.

The present embodiment can provide a semiconductor device wherein semiconductor chip 7 has a surface provided with an external connection electrode and a surface opposite that with the external connection electrode, abraded to reduce semiconductor chip 7 in thickness to allow the chip itself to flex in response to bending-force. As such, when printed circuit board 9 with semiconductor chip 7 packaged thereon receives force and thus bends, together with printed circuit board 9 semiconductor chip 7 can accordingly bend to alleviate stress in solder ball 6 or a solder connection so as to prevent the solder connection from breaking. Furthermore, applying resin of a low elastic modulus (a low Young's modulus) on the abraded surface of semiconductor chip 7, can reinforce thus-configured semiconductor chip 7 without affecting the bendability of the chip.

In the present invention a semiconductor chip has a surface provided with an electrode and a surface opposite that with the electrode, abraded to reduce the chip in thickness. As such, when the chip itself receives force

5 exerted to bend it, together with the printed circuit board the semiconductor chip can accordingly bend to reduce stress in a solder connection to prevent the solder connection from being damaged. Furthermore, applying resin of a low elastic modulus on the abraded surface of the semiconductor chip can protect the chip to eliminate the risk of the semiconductor chip chipping or being scratched. As such, the semiconductor chip can be handled more readily. As a result, the entirety of the semiconductor device can be mechanically more reliable.

10 Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.